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Assessment of L-H transition detection in ITER PFPO phases with synthetic diagnostics

A. Medvedeva[1], M. Schneider[1], S.D. Pinches[1], M. De Bock[1], X. Bonnin[1], S. Denk[2], S.H. Kim[1], A. Polevoi[1], A. Sirinelli[1], D. Vezinet[3]

[1] ITER Organization, Route de Vinon-sur-Verdon, 13067 St Paul-lez-Durance, France
[2] Massachusetts Institute of Technology, Institute of Advanced Energy, [3] CEA, IRFM
E-mail (speaker): Anna.Medvedeva@iter.org

One of the main objectives of the two ITER experimental Pre-Fusion Power Operation (PFPO) campaigns is the achievement of the H-mode confinement regime. This includes the characterization of the energy and particle confinement, the commissioning of the main plant systems in H-mode operation, and the establishment of the operational domain for ELM control and mitigation [1]. In order to facilitate access to H-mode, ITER foresees first operation in hydrogen and helium at 1.8 T / 5 MA and 2.65 T / 7.5 MA with an edge safety factor $q_{95} = 3$ for MHD similarity. This contribution summarizes the development of synthetic diagnostics to detect the L-H transition and the approach to it in ITER PFPO scenarios. In particular, it is crucial to determine to what extent the physical phenomena associated with the L-H transition can be characterized using the set of diagnostics available in PFPO. This study includes the evaluation of the conditions required to access the H-mode and the development of physical models of the L-H transition.

The H-mode is characterized by the development of an edge transport barrier, which guarantees higher temperatures and densities at the plasma core with strong gradients at the edge. At the same time as the confinement improves, the power distribution on the first wall and divertor targets changes. These effects can be measured by temperature and density diagnostics, as well as by diagnostics of energy deposition on the plasma facing components. The list of relevant ITER diagnostic systems includes microwave diagnostics (reflectometry, refractometry, ECE), interferometry, spectroscopic diagnostics, thermography, bolometry and Langmuir probes.

A major obstacle in experimental studies of plasma confinement is the difficulty of obtaining direct and local measurements in the hostile environment of the tokamak. In this context, a synthetic diagnostic, which models a real diagnostic and simulates its signal, becomes a very valuable tool for validation of predictive plasma simulations and interpretation of measurements. Given the plasma parameters from predictive simulations and the machine description of each diagnostic system, the diagnostics' signals can be computed. The simulation results and the machine descriptions are unified within the IMAS (Integrated Modelling and Analysis Suite) framework and the synthetic diagnostics are adapted to use standard Interface Data Structures (IDSs) for data exchange. For the development of synthetic diagnostics, use is made of software libraries created for the fusion community such as TOFU [2], CHERAB and Raysect [3]. These tools are particularly well suited to the calculation of the synthetic signal along a line-of-sight as well as to the tomographic inversion of measured emission in the visible, UV or X-ray range while taking into account multiple wall reflections.

In the framework of this project, the assessment of L-H transition detection relies upon comprehensive integrated plasma simulation efforts and uses advanced core and edge transport solvers like ASTRA [4], JINTRAC [5] and SOLPS-ITER [6]. The plasma simulations are coupled with the synthetic diagnostics in order to assess measurement capabilities and to optimize the performance of the diagnostics. This presentation will cover the development and application of the ITER synthetic diagnostics workflow, including components like DIP_TIP (interferometry), CASPER (spectroscopy) and ECRad (ECE).

References

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